DOCUMENT RESUME

ED 250 177 SE 045 153

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TITLE Clarifying the "A" in CAI for Learners of Different Abilities. Assessing the Cognitive consequences of Computer Environments for Learning (ACCCEL).
INSTITUTION California Univ., Berkeley. Lawrence Hall of Science.
SPONS AGENCY National Inst. of Education (ED), Washington, DC.
PUB DATE 84
GRANT 400-83-0017
NOTE 33p.; Paper presented at the Annual Meeting of the American Educational Research Association (68th, New Orleans, LA, April, 1984).
PUB TYPE Speeches/Conference Papers (150) -- Reports - Research/Technical (143)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS Aptitude Treatment Interaction; *Cognitive Ability; *Cognitive Processes; *Computer Assisted Instruction; *Computer Software; *Educational Games; Educational Research; Induction; Junior High Schools; Logical Thinking; Problem Solving; Student Characteristics; *Teaching Methods; Transfer of Training
IDENTIFIERS *Computer Games

ABSTRACT

This study investigated the degree to which 48 seventh and eighth grade students of different abilities acquired strategic planning knowledge from an intellectual computer game ("Wumpus"). Relationships between ability and student performance with two versions of the game were also investigated. The two versions differed in the structure and explicitness of instructional cues and the form of directions and feedback provided. The purpose of the game (which requires logical reasoning, strategic planning knowledge, and self-regulated learning skills) is to locate and kill a mythical monster while avoiding several hazards that impede safe movement through a warren of 20 interconnected caves. Results showed that more successful students acquired strategic planning knowledge by induction from examples and performed better on transfer tasks. Ability differences were also found. Both ability groups improved performance; in addition, high ability students, regardless of instructional treatment, performed better than less able students on the game and the transfer tasks. Considerations for further investigation of the relationships among learner characteristics and instructional variations in computer learning are discussed. Implications for the use of cognitively engaging software in educational settings are also discussed. (Author/JN)

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ED250177

Clarifying the "A" in CAI for Learners of Different Abilities

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Paper Presented at the annual meeting of the National Association for Research in Science Teaching, New Orleans, April 28, 1984.

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Abstract

The study investigated the degree to which students of different abilities acquired strategic planning knowledge from an intellectual computer game. The relationships among ability and student performance in the instruction were examined. Students learned a computer problem solving game under two forms of instruction. Performance was monitored interactively. Results showed more successful students (a) acquired strategic planning knowledge by induction from examples and (b) also performed better on the transfer tasks. Ability differences were found. Considerations for further investigation of the relationships among learner characteristics and instructional variations in computer learning are discussed. Implications for the use of cognitively engaging software in educational settings also are addressed.

Clarifying the "A" in CAI for Learners of Different Abilities

Considerable interest in the effects of computer learning has been generated over the past few years as technology has become an increasingly important focus of education. To date, there has been limited research on the cognitive consequences of computers. The ACCCEL (Assessing the Cognitive Consequences of Computer Environments for Learning) Project at the University of California attempts to address the need for systematic research in the area. The study described here is one in a series of studies that examines the effects of learning from cognitively demanding software.

One variable provides a common focus of investigation for the ACCCEL programming and software studies. That significant variable is the directness or explicitness of instruction. Research has shown that direct or explicit instruction benefits novices, young children, and students of low ability, but is not necessarily appropriate for all learners (Doyle, 1983). Indirect instruction may provide abler students with practice in higher-order cognitive skills. The "unstructuredness" of the instruction forces learners to respond actively in building their own comprehension of the material.

All learning involves both implicit and explicit knowledge, yet individuals differ in the degree to which they actively process such knowledge. Instruction can make forms of knowledge more or less salient. An instructional task focused on an obvious topic will also, in subtle ways, convey knowledge of a more

implicit nature, and it may model or illustrate particular modes of cognitive behavior.

The notion of planning toward a solution is important in understanding how students work through instructional materials. The organization required has been called strategic planning knowledge. Greeno (1978) defines strategic planning knowledge as the ability to set goals, choose appropriate action plans, and in general, organize cognitive activity so as to produce a solution to a problem. Strategic knowledge, as Greeno points out, is generally not an explicit part of the curriculum, although "it seems likely that many students acquire strategic knowledge by induction from example problems that present strategic principles implicitly" (p. 72).

The consistency and interactiveness of the response-feedback cycle in CAI creates a precise learning environment that forces students to make explicit their responses to the computer (Linn, Fisher, Mandinach, Dalbey, & Beckum, 1982). Although computers may force students to be explicit, the instructional support provided may be more indirect or implicit. Similarly, students may need to make inferences in traditional classrooms, but the instruction may be more explicit or direct. Students therefore must be able to organize information and plan toward toward a solution.

The concept of self-regulation is critical to understanding how students organize information, monitor performance, and plan performance routines. Corno and Mandinach (1983) define self-regulated learning as a student's active acquisition and transformation of instructional material. Information acquistion

processes include receiving stimuli, tracking information, and self-reinforcement ("alerting" and "monitoring"). Transformation processes include discriminating relevant from irrelevant information, and planning performane routines ("selectivity," "connecting," and "planning").

Self-regulated learning is seen as the highest form of cognitive engagement, using both acquistion and transformation processes. Variations on self-regulated learning are hypothesized between and within different tasks. The other forms of engagment are a focus on the task, management of resources, and recipiant learning. Task demands or features of instruction are seen to stimulate shifts in the form of cognitive engagment used in particular situations. Learning can become less self-regulated if the instructional environment assumes some of the self-regulation processes. Consequently, self-regulation is not necessarily appropriate not encouraged in all tasks.

Strategic planning knowledge and self-regulation are seen as important cognitive activities in computer learning environments. Yet, not all students are equally likely to acquire these skills and knowledge from traditional or computer instructional media. Individuals differ with respect to how they profit from instruction and learn most efficiently. Learners with different aptitude profiles learn better under different instructional methods (Cronbach & Snow, 1977). Some students can benefit most from instruction by a teacher or from highly structured instructional material, while others require less instructional support and still others learn most effectively with computerized tutors.

Assertions

This study addresses these issues and investigates the role of strategic planning and self-regulation in learning to solve an intellectual computer game. Specifically, the study examined the degree to which learners of different abilities acquired strategic planning knowledge and activated self-regulated learning skills from examples in computer-assisted instruction. The instruction encouraged acquisition of strategic planning, self-regulation, and logical reasoning.

Students who learn details may or may not benefit from instruction in strategic planning. Processing cues may need to be particularly salient and controlled for such students; this can be done with certain instructional methods such as computer-assisted instruction (CAI). Some students may be able to induce information about planning from less explicit examples. Such differences across students may be predictable from their scores on standardized achievement tests (Snow, 1980a; 1982). The following general questions were addressed:

1. Do students acquire strategic planning knowledge from alternative instructional methods such as CAI?
2. Do ability measures predict who will display strategic planning knowledge from this instruction?
3. How task specific are strategic planning and self-regulation? Do results transfer to non-CAI problem solving tasks?

Method

Wumpus

Wumpus is a computerized "hunt the monster" game in which the student is a hunter whose goal is to locate and kill the mythical creature Wumpus while avoiding several hazards that impede safe movement through a warren of 20 interconnected caves. Task analyses show the game to require logical reasoning, strategic planning knowledge, and self-regulated learning skills on the part of the players. A complete description of the game is found in Mandinach (1984).

Two versions of instructional material on Wumpus were designed. The two versions differed in the structure and explicitness of instructional cues and the form of directions and feedback provided. One version provided little to no learning support. It represented an attempt to activate students' existing cognitive structures and processes; that is, the instruction required students to assume responsibility for the task's processing demands. This activating instruction followed a discovery-learning paradigm (Bruner, 1961) in which students explored the instructional task with minimal cueing from the computer or the experimenter-instructor. The second version of instruction used participant modeling to reduce the information processing burdens. The instruction systematically modeled appropriate cognitive skills and game strategies, and gradually assisted learners to take over those strategies themselves (Corno & Mandinach, 1983). Unlike the activating version of instruction, modeling was expected to help less able learners develop strategic

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planning knowledge for this game as well as general self-regulation skills as the instruction concurrently circumvented their aptitude deficencies (Glaser, 1977).

Subjects and Sample Selection

The sample consisted of 48 seventh and eighth grade volunteers from a Bay Area junior high school. Scores on standardized achievement tests served as measures of verbal fluency (or general crystallized ability, *Gc*). A battery of group-administered ability tests assessed analytic reasoning (or general fluid ability, *Gf*). The *Gc*-*Gf* distinctions follow Cattell (1971) and Snow (1980b). To assure adequate representation on both *Gc* and *Gf* in the final sample, students were selected at random from the quadrants of an initial bivariate (*Gc* x *Gf*) ability plot. A general ability (*G*) score combined the *Gc* and *Gf* indices. The resulting sample consisted of 29 males and 19 females, distributed proportionately on *G*.

Instrumentation

Instrumentation included the standardized achievement tests, the reference battery that assessed fluid ability, and measures of computer knowledge, attributions for computer performance, and general reasoning skills. Measures of *Gc* were the reading, mathematics, and auditory subscales of the Stanford Achievement Test (Madden, Gardiner, Rudman, Kelley, & Merwin, 1973). The *Gf* measures were the Advanced Progressive Matrices, Set I (Raven, 1958), Letter Sets Test and Maze Tracing Speed Test (French, Ekstrom, & Price, 1963).

Procedures

The reference battery was administered in a group testing session. Thereafter, each student participated in several individual sessions with the experimenter. The first session was an introduction to the computer, the game, and its rules. This was followed by four instructional sessions. Each session contained 12 practice games and 12 instructional example sets. The order in which the games were presented was randomized by the computer to control for order and practice effects. Students received a game, and then a set of instructional examples. Alternation of games and instructional examples permitted the assessment of performance variations in two different phases of learning--instruction and gaming practice. These phase differences are described elsewhere (Mandinach, 1984). Students' responses and response latencies were recorded. Verbal responses were recorded on a cassette and in the experimenter's notes. Transfer tasks that required logical reasoning, self-regulation, and strategic planning skills were administered in two follow-up sessions. Interview protocols, response patterns, latencies, errors, and other Wumpus-specific measures of planning and reasoning ability were collected and analyzed.

A number of variables were considered. Wumpus performance measures included three gaming and five instructional variables. For simplification, the results discussed here focus on performance in the gaming phase. The practice or gaming phase provided the opportunity to apply the skills taught during instruction in a free-play or gaming situation through direct and unimpeded interaction with the computer. Cognitive engagement

data are reported elsewhere (see Mandinach, 1984; Mandinach & Corno, in press).

Results

Reference Battery Measures

This section presents results from the standardized achievement tests and reference battery. Standardized achievement tests provided evidence about crystallized ability profiles. Averages for the crystallized ability (Gc) tests were: reading, 189; mathematics, 186; auditory, 176; and battery composite, referred to as total, 187. The fluid ability (Gf) tests were the Advanced Progressive Matrices, Maze Tracing Speed Test, and Letter Sets Test. The Gf means were: Matrices, 8; Mazes, 30; and Letter Sets, 16. The aptitude tests showed a range of scores in this sample comparable to the samples on which the tests were normed.

The scores from the three Gf measures and the subscales of the achievement tests were standardized and combined to form the two ability composites. Scores on the Gc composite ranged from -5.78 to 4.28. The Gf composite ranged from -4.70 to 5.35. The Gc and Gf composites were combined to form a general (G) variable. G ranged from -8.15 to 7.82.

A Computer Knowledge Questionnaire provided a rough estimate of computer experience and familiarity. Response patterns that may have influenced performance on the experimental task were examined. Most students in the sample had used a computer in some capacity. However, only few had used a computer in any of their classes and had a computer at home. Furthermore, less than

one-quarter of the students had knowledge of a computer language (usually BASIC). The majority of the sample could be classified as computer novices.

Wumpus Gaming and Instructional Variables

Among the variables recorded during the gaming and instructional phases of the study, only some of special importance are examined here. Three gaming variables were

percent success - percent of games won;

error avoidance index - percent of unnecessary risks successfully avoided during beginning-game; and

penalty points - number of penalty points accrued divided by the number of moves per game.

The instructional variables were

deductions - points for deductions in the instructional examples;

decisions - points for information versus risk values of the selected route;

alternatives - number of alternative routes considered;

risks - number of risks considered; and

penalty points - average penalty points accrued in the instructional examples.

First, regression line data for the performance measures are examined. Correlational patterns then are traced. Finally, performance on the transfer tasks is described.

Regression analyses. Regressions of the primary Wumpus variables onto session number were examined for performance trends. Regression coefficients, intercepts, and standard errors were calculated. The intercepts reported here were the midpoints in

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the experimental timeline: that is, Time 2.5, or half-way between Sessions 1 through 4.

Percent success ranged from .00 to .46, with a median of .25 (Table 1). Success improved gradually over sessions ($\underline{b}$=.04). The ability to plan strategically and regulate one's own learning was measured by an index called "error avoidance." A high score on the index was seen to reflect a student's ability to consider alternative solutions, assess and avoid unnecessary risks, discriminate among stimuli, connect incoming information to existing data, and deduce critical information toward a solution. Error avoidance also improved gradually ($\underline{b}$=.01). Performance on this variable ranged from .08 to .94. Gaming penalty points decreased steadily over time ($\underline{b}$=-1.36). Penalty points ranged from 4.80 to 28.13. Note the regression coefficients reported here use different metrics.

Insert Table 1 about here

Regression lines for particular subsamples of students were examined (Table 2). Among the group differences reported, students in the modeling condition tended to perform better on two gaming variables: percent success and penalty points. No difference was noted on error avoidance. High ability students performed better on the gaming variables, but less able students tended to catch up.

Insert Table 2 about here

For the regression line data for the instructional variables for the entire sample, we return to Table 1. Performance on

instructional deductions ranged from 12 to 80.42. Students steadily increased the number of hazards deduced in the instructional examples (b 2.56). Similarly, improvement over time was noted for executive decisions (b=2.08). That is, students became more Wumpus-centered over time. Performance ranged from 42.90 to a maximum of 70. Performance on the alternative (b=-.02) and risk (b=-.17) indices declined over sessions. The range for alternatives was from 3.28 to 25.21; for risks, 0 to 20.62. Finally, instructional penalty points decreased substantially over time (b=-3.05). The number of penalty points ranged from 0 to 45.97.

Students who received the modeling instruction performed better and improved more over time on deductions, consideration of alternatives, and consideration of risks. The activating group improved more on executive decisions and instructional penalty points. These students started with more penalty points and were less Wumpus-centered, but improved their performance on both measures over time.

High ability students performed better on all of the instructional variables. However, on only instructional penalty points and consideration of alternatives did they consistently show greater improvement over time than the low ability students. The high ability students also performed well on instructional deducions and executive decisions. They improved their performance over time, but not as much as the low ability students.

Inspection of the regression lines indicated that specific subgroups of students responded differently to the instruction

rates for the Wumpus games. They also were more able to avoid initial and unnecessary risks. Low ability students accrued more penalty points than those in the high ability groups.

Insert Table 3 about here

Weaker relationships were found for the instructional variables. Performances on the five variables were related to *G*, *Gc*, and *Gf*. In particular, students high in *G* (r=.56), *Gc* (r=.56), and *Gf* (r=.38) gained more points on the decision index. Able students also gained fewer penalty points during instruction. Weaker correlations were found for instructional deductions, consideration of alternatives, and consideration of risks.

Relationships among several gaming and instructional variables were examined within and between the gaming and instructional phases of the study. Finally, the Wumpus variables were correlated with performance on the transfer tasks.

Table 4 presents the intercorrelations among the Wumpus performance measures. Note the figures on the diagonal are the reliabilities for the performance measures. In general, the correlations were higher within than between phases of the study. Particularly strong correlations were found among the gaming variables. Students who successfully achieved a solution avoided more unnecessary risks during beginning game (r=.66), and accrued fewer gaming penalty points (r=-.68). Students with lower error avoidance scores were assessed more penalty points (r=-.80).

Insert Table 4 about here

Percent success was most strongly related to decisions in the instructional phase (r=.56). Additionally, more successful students were better able to perform the deductions (r=.42) and gained fewer instructional penalty points (r=-.34). A similar pattern was found for error avoidance. Students who avoided initial risks made better decisions (r=.43), more deductions (r=.33), and acquired fewer penalty points (r=-.33). Gaming penalty points were strongly related to the instructional variables. Students who accrued penalty points did so during both gaming and instruction (r=.55). These students were less likely to consider alternatives (r=-.34) and risks (r=-.39), deduce relationships among the stimuli (r=-.60), and make appropriate decisions (r=-.62).

Instructional deductions were related to the other instructional variables. Students who were better able to deduce relationships among the stimuli also made more goal-oriented decisions (r=.48), considered risks (r=.45), alternatives (r=.57), and scored fewer penalty points (r=-.56). Students who considered risks also considered alternatives (r=.68). Finally, students who were seen as Wumpus-centered (high on the decision index) gained fewer penalty points (r=-.49).

Several gaming variables also were examined in relation to the primary measures. First, students who played more games per session accrued more penalty points per game (r=-.61) and avoided fewer initial risks (r=-.60). They also made fewer deductions (r=-.58) and considered fewer alternatives (r=-.52), and risks (r=-.58). A greater number of moves per game went with successful performance (r=.68), error avoidance (r=.73), and avoidance of

penalty points (r=-.87). Students who made larger numbers of moves per game deduced more relationships among the stimuli (r=.56), made more Wumpus-centered decisions (r=.55), considered more risks (r=.41), and acquired fewer penalty points (r=-.41). That is, these students stayed alive longer. Students who avoided risks during beginning game considered risks (r=.79) and gained fewer penalty points (r-=.62) and were more successful at Wumpus (r=.50).

Finally, the relationships among the primary Wumpus variables and the transfer tasks were examined (Table 5). These posttests were intended to assess specific cognitive processes. Both the Deductive Reasoning and Map Planning Tests were thought to require low-order planning, whereas Hurkle and Find the Errors required high-order planning. Deductive Reasoning, Hurkle, and Find the Errors also had logical reasoning components.

Insert Table 5 about here

The gaming and instructional variables were related to performance on the transfer tasks. Stronger correlations were found for the gaming variables (median r's were .35 for percent success, .50 for error avoidance, and -.50 for penalty points).

Students who performed on Wumpus also did well on the transfer tasks. However, certain performance measures and posttests were less related than others. In particular, students who made fewer mistakes, as measured by the number of acquired penalty points, were more successful on the posttests. The decision index also was strongly related to posttest performance.

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The near transfer task, Find the Errors, was slightly more related to Wumpus performance than were the far transfer measures.

Performance on the Transfer Tasks

It was expected that specific skills acquired through interaction with Wumpus would generalize to various tranfer tasks. Furthermore, students' ability profiles and the form of instructional support received were expected to mediate the transfer of cognitive skills. Five transfer tasks were administered, each assessing at least one of four skills hypothesized as necessary components for successful performance on the experimental task.

The Map Planning Test was used primarily as a speeded, low-order planning measure. The speeded restriction produced a wide range of performance. Scores ranged from 4 to 37, out of a possible 48 points. The average score was 17.3.

Hurkle and its efficiency score both required high-order planning, but primarily were used as measures of logical reasoning and transfer to another computer problem solving task. Scores on Hurkle ranged from zero to a perfect score of 12. The average was 7.8. An efficiency score assessed logical reasoning self-regulation, and planning. Some students were extremely efficient and planned their moves logically and effectively. Others used a completely haphazard approach to the task. Scores on the index ranged from -52 to 38, with an average of 7.9.

Find the Errors, a near-transfer task, measured the degree to which students applied strategic planning knowledge, logical reasoning, self-regulation, and in particular, Wumpus-specific knowledge to protocols of poorly played games. A wide range of

performance was observed, with an average of 19.5 out of a possible 40; scores ranged from 2 to 39. Several students exhibited an intimate understanding of Wumpus by debugging the protocols accurately. However, a few students had difficulty identifying even the most blatant errors.

The Deductive Reasoning Posttest was used as a measure of logical reasoning and self-regulated learning. The average score was 7.56.

The final transfer task was a Structured Interview and Teachback of the skills acquired through from Wumpus. Responses to the Teachback fell into several general categories of Wumpus knowledge. Students' responses focused on rules and information about Wumpus, risks and strategies, mapping and the use of study aids, and self-perception of their performance.

The vast differences among the students in their ability to discuss Wumpus became increasingly apparent during the interviews. Some students were unable to articulate even the simplest rules, yet were able to apply them in the gaming situations. Conversely, others were adept at explaining the game, but were unable to put into practice those principles. These differences were evident in the number of basic rules students discussed during the Teachback.

In general, students who performed better on Wumpus also did better on the transfer tasks and were more articulate in the Teachback/Interview. Ability influenced performance. High ability students did better on all of the posttests. Furthermore, students who received the activating instruction did slightly better than those in the modeling condition.

Discussion

The preceding section traced the change over four sessions of the performance measures that reflect strategic planning knowledge and self-regulated learning in an intellectual computer game. Self-regulated learning data are reported elsewhere (Mandinach, 1984). The influences of individual differences and instructional treatments on performance in Wumpus were examined. Transfer of targeted skills also was assessed.

Improvement of performance was noted in both treatment groups. However, no claim can be made that improvement was due to the treatments beacuse a practice-only group was not included in the design. Treatment differences were small, though students who received the modeling treatment performed better than others, on average, in the gaming and instructional phases of the study. Those who received the activating instruction did average slightly higher on the transfer tasks than the modeling group. Finally, students who performed better on Wumpus also did better on the transfer tasks.

Both ability groups improved their performance. High ability students. regardless of instructional treatment performed better than less able students on Wumpus and the transfer tasks. The high ability students performed slightly better under the modeling condition. Low ability students also performed better in the modeling treatment, but did not do nearly as well in the less supportive activing instruction.

Effective performance was affected by how students organized cognitive activity on Wumpus. Better players were able to

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integrate existing with incoming information, identify relations among elements, and monitor performance. More important, these students set goals and subgoals, and formed plans that led to attainment of those goals. Performance on the primary Wumpus variables prov.ded evidence of strategic planning and self-regulated learning, as did latency and error patterns.

These findings raised a pedagogical question about the use of educational software for instructional purposes. What became increasingly apparent was that certain students viewed Wumpus primarily as a game rather than an educational activity. Some students tended to revert to a "gaming approach" to the instructional task when frustrated; others accepted the task as instructional. Such observations have implications for use of educational software and in particular, games and simulations. Games and simulations tend to be more cognitively engaging, stimulating, and motivational than traditional CAI, but not all students perceive such software as a learning experience. Some students will take a line of least resistence, regardless of the educational task. Consequently, caution is necessary when selecting software for subsets of students, despite the educational intent.

On the other hand, using an educational game as an experimental task had positive effects, both from an instructional and research perspective. Wumpus provided a stimulating yet fun educational experience. Most students took the task seriously and tried to learn from the game. Some students with less than strong academic records did very well. Wumpus capitalized on the unique features of the learning environment and on the characteristics of

the computer game that make them potentially powerful educational tools.

A further concern here is who benefited from interaction with Wumpus and which instructional treatment was most effective. Low ability students gained more from the modeling than the activating instruction, whereas high ability students were able to profit from both treatments. In essence, this was a "rich get richer" situation. The intent was to maximize the interaction among instructor, computer, and student, hoping that such individualization would positively influence students who would profit from the instruction on their own. Perhaps it is naive to expect large improvement after only four hours of instruction, especially from slower students, but the individualization should have counter-balanced that to some extent. Wumpus emphasized on the acquisition of higher-order cognitive skills and secondarily, their transfer to related tasks. Acquisition of such skills is not accomplished from short-term instruction, but rather accumulated from extended exposure to problem solving situations.

Perhaps a more long-term and more explicit instructional treatment would assist learners to acquire these higher-order skills. The term explicit here is not analogous to direct instruction. Instead, the term is used as a means by which to explain the connections between problem solving tasks. That is, making explicit the connections between the skills used in Wumpus and other problem solving situations should facilitate acquisition and transfer of those skills.

Results indicated that students who received the more direct modeling instruction performed better on Wumpus, whereas those in

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the activating instructional group were better able to transfer targeted skills to related tasks. This finding is commensurate with studies that differentiate direct from indirect instruction (Doyle, 1983, Shulman & Keislar, 1966). However, making explicit the connections between tasks has different educational implications than providing direct or explicit instruction. It allows students to observe how skills generalize across educational activities, without relieving information-processing demands from the students.

Finally, the present study addressed the issue of whether students can acquire strategic planning knowledge and engage self-regulated learning processes with appropriate instruction. An integral factor in such cognitive activity was response sensitivity to feedback. Computers make feedback particularly salient, precise, and interactive. How students attended to, organized, and used such machine feedback was critical in Wumpus, and more generally, in most computer environments. Response sensitivity to feedback is seen as an important component of cognitive engagement. ACCCEL continues to explore the role of response sensitivity in learning from computers.

Wumpus is a complex problem solving task that has been shown to require strategic planning knowledge and self-regulated learning. Some students were able to acquire aspects of this knowledge and skill with minimal instructional support; some needed more explicit assistance; still others were unable to acquire higher cognitive skills even with relatively intensive instruction. Because Wumpus was a computer problem solving task, it was possible to capitalize on the unique characteristics of

that learning environment (Dalbey & Linn, 1983; Mandinach & Fisher, 1983). These characteristics, in conjunction with the complexity of the task, helped to foster knowledge and skill acquisition for certain students who otherwise may have been unable to profit from the instruction. High ability students benefited from both instructional conditions, whereas low ability students performed hetter when given particpant modeling instruction.

Generally, students who performed better on Wumpus assessed risks, made appropriate logical inferences, considered alternative solutions, and planned toward a solution. In contrast, less successful students failed to distinguish relevant from irrelevant data, connect new to old information, and monitor their progress toward a correct solution. In other words, more successful students used self-regulated learning as they completed the Wumpus modules. Engaging in these processes was critical not only for effective strategic planning but also for Wumpus success. Evidence for these differences were reflected in latency, response, and error patterns.

Individual differences in ability influenced the degree to which students were able to profit from the two instructional treatments. Apparently, some students were able to acquire strategic planning knowledge by induction from examples in CAI, while others required additional support from the instruction. Specifically, those more likely to benefit from minimal instructional support were high ability students. However, some high ability students were unable to acquire strategic planning knowledge and self-regulated learning skills with only the minimal

support of the activating treatment. Still other high ability students benefited from the more direct modeling instruction. Low ability students generally were unable to profit from the activating instruction. These students needed more explicit assistance and were more likely to benefit from the additional support in the modeling instruction. However, a number of low ability students and also a few in the high ability group never displayed evidence of strategic planning and self- regulation, regardless of the instructional treatment. Additionally, performance on Wumpus and the outcome measures was related. Students who were more successful on Wumpus also performed better on the posttests and apparently displayed strategic planning and self-regulated learning skills on both sets of tasks.

These findings provided evidence supporting the three general questions guiding the research. The study also produced a number of unanticipated results that indicate possible lines of future research. Further examination of the effects of learner characteristics and instructional variations on performance are indicated. Subsequent research will extend the present study and attempt to elucidate the role of strategic planning knowledge and self-regulated learning in Wumpus and other intellectual computer activities.

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Footnote

[1]The author wishes to thank Lyn Corno and Lee Cronbach for their helpful advice. This study was funded by the National Institute of Education under the Grant No. 400-83-0017. Any opinions, findings, conclusions, or recommendations expressed in this paper do not necessarily reflect the views of the National Institute of Education.

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Table 1

Regression of the Wumpus Performance Measures

onto Session Number

Performance Measure	b	Intercept at 2.5	SEE
Percent Success	.04	.30	.23
Error Avoidance	.01	.42	.48
Gaming Penalty Points	-1.36	16.11	8.00
Deductions	2.56	43.03	20.52
Decisions	2.08	63.49	8.43
Alternatives	-.02	10.66	6.93
Risks	-.17	4.88	5.98
Instructional Penalty Points	-3.05	14.76	15.21

Table 2

Differences in Regression Lines for Instructional and Ability Groups

Variable and Group	N	Difference in b	Difference in Intercept
Percent Success			
Activating - Modeling	24-24	-.04	-.05
High G - Low G	24-24	.02	.19
Error Avoidance			
Activating - Modeling	24-24	.00	-.01
High G - Low G	24-24	-.02	.23
Gaming Penalty Points			
Activating - Modeling	24-24	-.88	.82
High G - Low G	24-24	-.12	-9.75
Deductions			
Activating - Modeling	24-24	-2.74	-7.69
High G - Low G	24-24	1.08	13.67
Decisions			
Activating - Modeling	24-24	1.63	-1.91
High G - Low G	24-24	-2.11	6.63
Alternatives			
Activating - Modeling	24-24	-.04	-1.68
High G - Low G	24-24	1.16	1.84
Risks			
Activating - Modeling	24-24	-.72	-1.84
High G - Low G	24-24	-.54	1.84
Instructional Penalty Points			
Activating - Modeling	24-24	-2.76	3.36
High G - Low G	24-24	-1.58	-11.42

Table 3

Correlations of Ability Measures with
Main Wumpus Variables

	Gaming Variables			Instructional Variables				
	Percent Success	Error Avoid	Penalty Points	Deduc- tions	Deci- sions	Alter- natives	Risks	Penalty Points
Raven	.38	.37	-.48	.22	.27	.17	.23	-.34
Mazes	.33	.10	-.30	.17	.28	-.05	-.13	-.13
Letter	.42	.37	-.48	.30	.37	.31	.31	-.48
Reading	.33	.34	-.36	.20	.44	.15	.16	-.19
Math	.56	.55	-.61	.32	.56	.25	.29	-.38
Auditory	.40	.46	-.56	.25	.46	.26	.20	-.25
Total	.44	.50	-.51	.20	.50	.20	.20	-.24
Deduction	.49	.40	-.52	.44	.55	.23	.29	-.34
G	.58	.51	-.66	.34	.56	.26	.25	-.42
Gc	.50	.52	-.59	.30	.56	.25	.25	-.32
Gf	.48	.35	-.53	.29	.38	.18	.17	-.40

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Table 4

Intercorrelations of Wumpus Measures
(Estimated for Two Independent Series of Four Sessions Each)

	Gaming Variables			Instructional Variables				
	Percent Success	Error Avoid	Penalty Points	Deductions	Decisions	Alternatives	Risks	Penalty Points
Percent Success	.70							
Error Avoidance	.66	.92						
Penalty Points	-.68	-.80	.90					
Deduction	.42	.33	-.60	.79				
Decisions	.52	.43	-.62	.48	.67			
Alternatives	.12	.30	-.34	.45	.30	.71		
Risks	.22	.27	-.39	.57	.28	.68	.78	
Penalty Points	-.34	-.33	.55	-.56	-.49	-.32	-.32	.75

Note: Figures on the diagonal are reliability coefficients.

Table 5

Correlations of Wumpus Measures with Transfer Tasks

	Map Planning	Hurkle	Hurkle Efficiency	Find the Errors	Deductive Reasoning	Median
Percent Success	.55	.54	.55	.53	.60	.55
Error Avoidance	.41	.47	.54	.56	.50	.50
Gaming Penaly Points	-.43	-.56	-.60	-.64	-.51	-.50
Deductions	.34	.42	.39	.42	.34	.40
Decisions	.46	.66	.64	.44	.41	.45
Alternatives	.07	.17	.19	.33	.24	.20
Risks	.18	.24	.21	.40	.33	.25
Instructional Penalty Points	-.37	-.41	-.40	-.35	-.36	-.35